NOISE CONTROLLER FOR CONTROLLING NOISE AND METHOD OF REMOVING NOISE

CONTINUATION INFORMATION

This application is a continuation in part of application 08/970,455 filed on November 14, 1997, the entirety of which is hereby incorporated by reference.

FIELD OF THE INVENTION

This invention relates to a noise controller and a method of removing noise. More particularly, this invention relates to a noise controller for actively controlling noise, such as motor or actuator noise from a household electric appliance, and a method of actively removing the noise.

BACKGROUND OF THE INVENTION

When a progressing wave having a constant amplitude and phase encounters a wave having the opposite amplitude and phase, the progressing wave is canceled based on a concept known as destructive interference.

FIG. 1 is a drawing showing the principle of actively controlling noise, wherein generated noise is canceled by an artificial sound using the principle of destructive interference. Applying this principle, as illustrated by FIG. 2, it is possible to cancel a noise signal N by duplicating (N + S) an artificial signal S having the same amplitude and opposite phase.

FIG. 3 is a block diagram showing the principle of actively controlling the noise according to the prior art. The conventional noise controller comprises a sensor part 1 for perceiving the noise signal, a signal amplifying part 2 for amplifying the perceived noise signal, a first low-pass filtering part 3 for low pass filtering the amplified noise signal, a digital signal processor (DSP) 4 for processing the amplified low pass filtered noise signal without phase delay, a microcomputer part 5 for also processing the amplified low pass filtered noise signal from the first low-pass filtering part 3 in parallel with the DSP 4, a second low-pass filtering part 6 for low pass filtering the control noise signal from the DSP 4, an electric power amplifying part 7 for electric power simplifying the control noise signal, and an output part 8 for outputting the electric power amplified noise control signal.

The operation of the above-identified prior art is described in detail hereinafter by FIG. 3 to FIG. 5.

The sensor part 1 perceives the noise signal X(k) using a micro phone (not illustrated). The signal amplifying part 2 amplifies the noise signal X(k) perceived by the sensor part 1 and outputs the amplified signal to the first low-pass filtering part 3. The low-pass filtered noise signal X(k) from the low-pass filtering part 3 is changed into a digital signal by an analog-to-digital (A/D) converter (not illustrated) in the DSP 4. A control signal, which has same amplitude but opposite phase to the noise signal, is output through a digital to

analog (D/A) converter (not illustrated). The DSP 4 initializes the system and determines a degree of the filter.

The low-pass filtered noise signal X(k) from the first low-pass filtering part 3 is changed into a digital signal by an analog-to-digital (A/D) converter (not depicted) of DSP 4, then, as shown in detail by FIG. 4, the digital version of noise signal X(k) is output through a control target system 4a in the DSP 4. At the same time, a digital filtering coefficient controlling part (DFCCP) 4b computes a digital filtering coefficient based on the analog low-pass filtered noise signal X(k) received from the first low-pass filtering part 3, and outputs a modified digital filtering coefficient signal Y(k). Y(k) is a digital version of the output signal generated from the output part 8.

A mixer 4c in the DSP 4 outputs a residual noise signal E(k) by mixing an artificial sound output from the system 4a with the digital filtering coefficient signal Y(k) modified from the DFCCP 4b.

The DFCCP 4b in the DSP 4 adjusts the digital filtering coefficient signal Y(k) based on feedback of the residual noise signal E(k) to a level where the residual noise signal E(k) is minimized. The signal is converted by a digital-to-analog (D/A) converter (not depicted) and outputted as the control signal to the second low-pass filtering part 6.

The second low-pass filtering part 6 low-pass filters the control signal by DSP 4 and outputs the result. The electric power amplifying part 7 amplifies

the signal from the second low pass filtering part 6 and outputs the electric power amplified signal to the output part 8, which actually generates the canceling noise.

The above-identified apparatus requires a DSP chip, which is expensive. Because the conventional system and method of perceiving and controlling noise requires the DSP chip to be applied to each household electric appliance, such as a refrigerator and a washing machine, it is prohibitively expensive.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a noise controller for actively controlling noise, for instance, from a motor or actuator noise generated by a household electric appliance. Such motor or actuator generates a noise that is predominantly regular, i.e., the noise has predictable frequencies. For example, the frequencies are likely to be some multiple of 60Hz, which is the frequency of household electric power.

It is another object of the present invention to actively remove the noise by using the noise controller.

In order to achieve the above-mentioned objects, a noise controller in accordance with the present invention comprises a sensor part perceiving a noise and outputting a noise signal corresponding to said noise, a phase perceiving part perceiving a phase of said noise signal and outputting a phase

signal; and a micro computer part generating a noise control signal based a residual noise signal and an error variation signal.

Further, to achieve the above-mentioned objects, a method to actively control noise comprises perceiving a noise and generating a noise signal, perceiving a phase of said noise signal and generating a phase signal; and generating a noise control signal based a residual noise signal and an error variation signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing showing a prior art principle of an actively controlling a noise.

FIG. 2 is a drawing illustrating how noise is canceled in the prior art by duplicating characteristics of a noise signal N using an artificial signal S.

FIG. 3 is a block diagram showing a prior art system employing the principle of actively controlling noise.

FIG. 4 is a block diagram showing how the noise is actively controlled in a DSP of the prior art system of FIG. 3.

FIG. 5 is a flow-chart describing the process used to actively control noise in the DSP of the prior art system of FIG. 3.

FIG. 6 is a block diagram showing a system employing the principle of actively controlling noise according to the present invention.

FIG. 7 is a block diagram showing how noise is actively controlled in a microcomputer of the system of FIG. 6.

FIG. 8 is a flow-chart describing the process used to actively control noise in the microcomputer of the system of FIG. 6.

FIG. 9 is a drawing showing a control rule and generating an index data table. And

FIG. 10 is a diagram showing details of the phase perceiving part.

DETAILED DESCRIPTION OF THE INVENTION

Some of the preferred embodiments of the present invention are described in detail hereinafter based on the accompanying drawings.

Referring to FIG. 6, the noise controller in accordance with the present invention comprises a sensor part 101 for perceiving a noise signal, a signal amplifying part 102 for amplifying the noise signal from the sensor part 101, a first low-pass filtering part 103 for low-pass filtering the noise signal from the signal amplifying part 102, a phase perceiving part 104 for perceiving a phase of the low-pass filtered noise signal from the first low-pass filtering part 103, a micro computer part 105 for processing the noise signal from the first low-pass filtering part 103 and the phase of that signal perceived by the phase perceiving part (PPP) 104 without delay in phase, a second low-pass filtering part 106 for low-pass filtering the noise signal from the micro computer part

105, and electric power amplifying part 107 for electric power amplifying the noise signal from the second low-pass filtering part 106, and an output part 108 for outputting the electric power amplified signal from the electric power amplifying part 107 to the sound acoustical sound field.

The operation of the noise controller having the above-identified structure is described hereinafter by accompanying FIG. 7 to FIG. 9.

The sensor part 101 perceives the noise signal X(k) in the sound acoustical sound field using a microphone (not illustrated) or the like. The noise signal may also be perceived through other ways, such as directly sensing the noise generator through mechanical, electrical, or acoustical methods. The signal amplifying part 102 amplifies the noise signal X(k) perceived by the sensor part 101 and outputs the amplified noise signal to the first low-pass filtering part 103. The microcomputer is interrupted and changes the amplified low-pass filtered noise signal X(k) received through the first low-pass filtering part 103 into a digital signal using an analog-to-digital (A/D) converter (not illustrated) (Step S1). At the same time, the phase perceiving part 104 detects and outputs the phase of the amplified low-pass filtered noise signal X(k) received through the first low-pass filtering part 103 (Step S2).

~~As shown in FIG. 10, the phase perceiving part 104 includes a transformer 1002, a full-wave rectifier 1004, a pressure sensitive circuit 1006,~~

and a ~~bandpass filter 1008. In FIG. 10, B represents the noise and A represents the canceling noise. Mathematically, the relationship is as follows:~~

~~If B = sinù$_{o}$t then A = -sin(ù$_{o}$ + á)t~~

~~such that A + B = sin(ù$_{o}$ + á)t + sinù$_{o}$t = 0~~

~~where -180° á 180°.~~

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The noise is cancelled based on the phase shift according to the variation of á.

The microcomputer part 105 outputs a digital version of the the noise signal X(k) through a control target system 105a, as shown in FIG. 7. The microcomputer part 105 also generates a modified signal Y(k), which is converted to an analog signal by a digital-to-analog converter (not illustrated).

In a control rule controlling part (CRCP) 105b of the microcomputer part 105, an input value and output value are compared to each other. More specifically, in CRCP 105b, a residual noise signal E(k) output from a mixer 105c of the microcomputer 105 and a modeling value of the noise signal X(k) are compared to each other one-to-one using a neural network, as shown in FIG. 9.

Ins A2

Mixer 105c of microcomputer part 105 calculates and outputs an error signal and an error variation signal of a residual noise signal by mixing the noise signal X(k) output from the system 105a with the signal Y(k) output from the CRCP 105b (Step S3) according to the following equation:

$E(k) = X(k) - Y(k)$, $\Delta E(k) = E(k) - E(k-1)$,

where $E(k)$ is the residual noise signal, and $\Delta E(k)$ is error variation signal of the residual noise signal.

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Using an index table of the memory (not illustrated) within the microcomputer memory, the microcomputer part 105 determines a phase that is opposite the phase of the phase signal corresponding to the noise signal $X(k)$, and uses that phase to develop the phase of an artificial sound signal to be output through a digital-to-analog (D/A) converter (not illustrated) to second low-pass filter 106 (Step S4).

Thereafter, the CRCP 105b microcomputer 105 changes the artificial sound signal $Y(k)$ to reduce the error of the residual noise signal $E(k)$ to zero. The artificial sound signal $Y(k)$ is changed based on feedback of the error of the residual noise signal $E(k)$ output from the mixer 105c based on the equations discussed above.

The second low-pass filtering part 106 then filters the analog signal output from the microcomputer part 105. Further, the electric power amplifying part 107 amplified the analog signal output from the second low-pass filtering part 106 and outputs the electric power amplified signal to the acoustical sound field (not shown) through the output part 108 (Step S5).

The above process is continually executed to remove the error signal of the residual noise signal $E(k)$.

In accordance with the present invention, it is possible to actively control the noise being generated in motors or actuators of household electric appliances such as a refrigerator or washing machine.

While the described embodiment represents the preferred form of the present invention, it is to be understood that modifications will occur to those skilled in the art without departing from the spirit of the invention. The scope of the invention is therefore to be determined solely by the appended claim.